REPORT TO MAYOR AND COUNCIL NO: 07-198

Council Meeting: June 5, 2007

SUBJECT: Use of 'Rubber Sidewalks' Adjacent to City Street Trees – Study Issue

REPORT IN BRIEF

As part of the 2007 Study Issue Workshop held on December 15, 2006, Council ranked this as a priority issue for study on the use of "rubber sidewalks" as a mitigation measure to reduce concrete sidewalk displacement adjacent to City street trees (see Attachment A). The City of Sunnyvale has approximately 37,000 street trees flanking city sidewalks. Ninety-five percent of sidewalk repairs are due to tree roots displacing the concrete. Sunnyvale's Concrete Maintenance program employs practices that protect street trees while mitigating the concrete/tree root conflicts.

One of the most recently publicized techniques being tested to help mitigate concrete/tree root conflicts is the use of "rubber sidewalks" made from ground recycled tires. Currently there are sixty U.S. cities testing rubber sidewalk panels. Of the eleven San Francisco Bay Area cities, Redwood City has been testing and using rubber sidewalk panels since inception of the panels in 2001.

The current rubber sidewalk panels are manufactured by Rubbersidewalks, Inc. and are made from ground tires using a polyurethane binder forming a panel 2' x 2.5' x 1.875 inches thick. Rubbersidewalks, Inc panels are made of 100% California recycled tires which make them eligible for grant funding from the California Integrated Waste Management Board. The Tire-Derived Product (TDP) Grant reimburses government entities and agencies for projects diverting at least 2,500 used tires from the waste stream. Further discussion of the total cost is described under the Fiscal Impact section of the report.

The longevity and maintenance of the panels is unknown at this time. Redwood City staff states that their experience to date with rubber sidewalk sites have shown no deflections caused by expanding or regenerating tree roots with the oldest site being five years old.

Staff is recommending that Council give direction to install test sites for further research on the use of rubber sidewalk panels as a substitute for concrete sidewalk adjacent to trees. Rubber panels are one of several alternatives that could be used for mitigating concrete/tree root conflicts.

BACKGROUND

During a presentation to Council on November 28, 2006 regarding a potential study issue on the use and sustainability of large street tree species, a Sunnyvale resident suggested the City use "rubber sidewalks" as a mitigation measure to avoid concrete sidewalk replacement caused by street tree roots.

On December 15, 2006, Council identified this as a priority issue for study in calendar year 2007.

EXISTING POLICY

Land Use and Transportation Element

Goal C 3 Attain a Transportation System that is Effective, Safe, Pleasant, and Convenient

Policy C 3.5 Support a Variety of Transportation Modes

Action Statement C3.5.2 Require Sidewalk installation in Subdivisions

DISCUSSION

Sunnyvale has an inventory of approximately 37,000 street trees flanking city streets. This puts nearly all of the street trees in close proximity to public and private concrete. Ninety-five percent of all sidewalk and curb and gutter displacements are tree root related. The Concrete Maintenance Program (217) has a specific service delivery plan that provides tree root protection and control at sidewalks and curbs and gutters by any or all of the following procedures:

- Install root control materials at sidewalks, curb and gutters displaced by tree roots.
- Install special sidewalk paving material as an alternative to concrete where beneficial to street trees.
- Install or specify root control materials at new sidewalks with new street trees.
- Adjust sidewalk and curb alignments to allow for tree trunk and root growth of adjacent trees.

Currently the Concrete Maintenance program mitigates sidewalk hazards and repairs and/or replaces sidewalks as well as protects the City's street trees. See Attachment B for a complete discussion of tree root development and how tree roots damage sidewalks. Also see Attachment C for current concrete maintenance program practices in mitigating tree root/concrete conflicts.

The Concrete Maintenance program has an activity that provides funding for alternative sidewalks. To date, two alternatives have been piloted: Interlocking Concrete Pavers and Structural Soil. Interlocking concrete pavers are commonly used as an alternative to poured in place concrete for sidewalks, patios, driveways, etc. Interlocking pavers have been used in several locations within Sunnyvale as test sites. The first interlocking paver site was installed in 2000 at the commercial property owned by Sunnyvale at 1024 Morse Ave. To date, the interlocking pavers have performed well as a substitute for poured concrete sidewalks. In 2003 some of the pavers became displaced at the Morse Avenue site. Staff discovered adventitious roots had grown into the sand base layer under the pavers. The process of removing the pavers, the offending roots and reinstalling the pavers was simple. Staff is now using pavers at other locations and continues to monitor the performance of these test sites. Concrete interlocking pavers is a long term alternative to poured concrete for sidewalks with adjacent trees. (See Attachment D for further discussion of the test sites.)

Staff is testing Cornell University Structural Soil. Structural soil is a special base rock material used in new sidewalk installations. Its function is to allow young tree roots from recently planted trees to grow in and through it. Structural soil is not used on existing tree sites with established mature roots. There are four test sites and all of the test sites to date have performed well. There have been no displacements to date with the use of structural soil under sidewalks. (See Attachment D for further discussion of the test sites.)

Rubber Sidewalks

The sole manufacturer of a rubber sidewalk material is Rubbersidewalks, Inc., located in Gardena, CA. Rubber sidewalk panels are a new commercial product that uses 100% recycled California crumb rubber with a polyurethane resin binder. Panels are made 2' x 2' or 2' x 2.5' by 1.875 inches thick and weigh 10.8 pounds per square foot. The panels come either plain grey-black or with an epoxy skid resistant color coating. (see Attachment E and F for panel information.)

The density of the panel is hard enough that pedestrians will notice little difference from concrete when walking on the panels. Pedestrians using wheel chairs or walkers can traverse the panels without difficulty. As a walk-on material, the rubber panels by Rubbersidewalks, Inc are a viable sidewalk material.

As listed on Rubbersidewalks, Inc website, there are over sixty U.S. cities that have installed Rubbersidewalks' panels with forty-two being California cities. Of the California cities, eleven are San Francisco Bay Area cities. The original experimenter and the city with the most experience with rubber sidewalks in the Bay Area is Redwood City. Redwood City has installed rubber sidewalk

panels from some of the first iterations of panel production by Rubbersidewalks, Inc.

Redwood City contracts out installation of the panels. The Redwood City arborist inspects tree roots when the old concrete sidewalk is removed and will identify roots in need of removal prior to installing a panel. A crushed granite material is applied and compacted over the existing roots and the rubber panels are installed over the granite base material. The panels attach to each other using fiberglass dowels. The open edges of the panels are held in place with an aluminum channel that is nailed into the base rock material and soil with twelve-inch spikes. The abutting ends of the panels are wedged firmly against the remaining concrete sidewalk ends.

The longevity of the panels is unknown. Rubbersidewalks, Inc claims twenty years for their product while claiming that concrete only has five years before tree roots will cause damage and will require replacement. Redwood City staff states that their experience to date with rubber sidewalk sites have shown no deflections caused by expanding or regenerating tree roots with the oldest site being five years old. However, some of the original panel installations and the poured in place sites have shown surface deterioration. The most recent panels have an epoxy skid resistance coating that has shown some wear.

Rubbersidewalks, Inc. comments on but does not include ongoing maintenance cost in their cost comparison between rubber sidewalks and concrete. This cost is anticipated but unknown. When roots, in time, uplift the rubber panels they will have to be removed and reinstalled after these roots are mitigated. Redwood City does not have a cost benefit analysis but speculates that the longevity of trees will be improved. From our experience with concrete pavers, roots may lift the pavers within five years of installation. Rubber sidewalks would be similar.

As a substitute for concrete sidewalk adjacent to trees; rubber panels are one of several alternatives that could be used for mitigating concrete/tree root conflicts.

FISCAL IMPACT

The Concrete Maintenance program activity *217240 – Install Sidewalks with Alternative Materials* – is funded at $13,228.78 for Fiscal Year 2006/07. This activity provides the Concrete Maintenance program with a small amount of funding to experiment with alternatives to poured in place concrete sidewalks.

Rubbersidewalks, Inc. 2' x 2.5' panels along with associated fiberglass dowels, aluminum edging and support spikes cost $6.50 per square foot. The contract price in Redwood City for installation of rubber sidewalk panels which includes

removal of displaced concrete sidewalk, root removal, base rock and geotextile installation and panel is $32.30 per square foot.

The cost for concrete replacement has gone up significantly from last Fiscal Year. In FY 2005/06, the contract price for sidewalk replacement averaged $8.50 per square foot. This Fiscal Year, 2006/07, the sidewalk replacement cost averages $11.55 per square foot, a 36% increase.

City staff performs tree root mitigation for all sidewalks where tree roots are the primary cause for concrete replacement. Tree root mitigation adds an average of $4.80 to the square foot cost for sidewalk installation bringing the total cost for sidewalk replacement to an average of $16.35 per square foot. The use of rubber sidewalks as a replacement for poured in place concrete would increase the total cost of sidewalk replacement by 97% ($16.35 vs. $32.30). Grant funding for rubber sidewalks would reduce the cost by $6.50 per square foot.

It is difficult to analyze rubber sidewalks with such a short history of the product. From experience with interlocking concrete pavers, staff estimates roots could require mitigation every five years. Table 1 below quantifies a twenty year cost projection comparing concrete and pavers with rubber sidewalks.

Tire-Derived Product (TDP) Grant Program

The California Integrated Waste Management Board offers grants for projects using products that divert waste tires from landfills. To be eligible, a project must at least divert the equivalent of 2,500 passenger tires. The Rubberside-walks, Inc. rubber sidewalk product is a 100% California recycled tire product. One square foot of Rubbersidewalks, Inc. panel equals one recycled tire. Therefore, at least 2,500 square feet of rubber sidewalk would have to be installed to be eligible for this grant funding. At $6.50 per square foot the minimum grant would be $16,250. The TDP Grant only reimburses for tires diverted at a cost of up to $7.00 per tire diverted. The cost of the Rubbersidewalks, Inc product would be eligible for 100% reimbursement.

The cost of installation is not reimbursable and would be an expense to the City. Contractor cost as quoted from Redwood City information puts the cost of installing 2,500 square feet of rubber sidewalk at approximately $64,500.

The cost of installing rubber sidewalks adjacent to trees is roughly twice the cost of poured in place concrete and approximately 58% more when grant funding is included. Currently, the demand for sidewalk replacement is much greater than the budget available for this work. Fiscal Year 2006/07 funding for sidewalk and curb and gutter replacement is $441,525. The value of the deferred sidewalk and concrete replacement is now at $2,800,000. The contract

prices this year have risen significantly for concrete replacement, thus, reducing the quantity of sites that can be replaced. Of the over 1,080 pending replacement sites, we can only replace 160 sites this fiscal year. The use of rubber sidewalks would further reduce the sites that could be repaired without an increase in funding. All pending replacement sites are monitored annually and kept safe until the site is replaced.

Although funding from the Tire Derived Product Grant would assist with the cost of the panels, installation cost for rubber sidewalks would be significantly higher than the cost for poured concrete.

Table 1

Cost Comparison **Cost per Square Foot**	**Concrete Sidewalk***	**Rubber Sidewalk**	**Interlocking Pavers**
Initial Installation			
Materials	$0.00	$6.50	$3.90
Installation	$11.55	$21.00	$15.00
Root Mitigation	$4.80	$4.80	$4.80
	$16.35	$32.30	$23.70
Grant Funding			
Minus Grant Funding	$0.00	($6.50)	$0.00
Cost per Square Foot	**$16.35**	**$25.80**	**$23.70**
20 Year Cost Projections**			
5 yr maintenance	$0.00	$4.80	$4.80
10 yr maintenance	$0.00	$4.80	$4.80
15 yr maintenance	$16.35	$4.80	$4.80
20 yr maintenance	$0.00	$32.30	$4.80
	$16.35	$46.70	$19.20
Total Cost at 20 yrs	**$32.70**	**$72.50**	**$42.90**
Total Cost (2,500 Sq. Ft.)	$40,875.00	$64,500.00	$59,250.00

*Installation included cost of materials
**The 20 year cost projection is based on limited experience with the use of interlocking pavers. Concrete replacement at 15 years is based on sites without any root barriers.

A project to install 2,500 square feet of rubber sidewalk would equate to approximately 50 sites. The expense of maintaining the fifty sites has not been evaluated but there would be ongoing expenses as well as future replacement costs. The longevity of the product is unknown and will have a future replacement cost. When roots grow up under the rubber panels and deflect the rubber to the point where it is a tripping hazard, the panels will have to be removed, roots below mitigated and panels reinstalled.

PUBLIC CONTACT

Public Contact was made through posting of the Council agenda on the City's official notice bulletin board, posting of the agenda and report on the City's web page, and the availability of the report in the Library and City Clerk's Office.

ALTERNATIVES

1) Purchase and install rubber sidewalk panels to test the product at ten test sites in Fiscal Year 2007/08 using labor funded by Program 217 – Concrete Maintenance. This alternative will reduce concrete sidewalk replacement by eighteen sites which means ten sites would be rubber instead of concrete and eight other sites would not be installed.

2) Purchase and install rubber sidewalk panels to test the product at a number of sites to be determined by Council in Fiscal Year 2007/08 using labor funded by Program 217 – Concrete Maintenance. With rubber sidewalks costing more than poured concrete, this alternative will reduce concrete sidewalk replacement by an amount determined by the number of rubber sidewalk sites installed.

3) Direct staff to pursue funding for the use of rubber sidewalk panels using California Integrated Waste Management Board Tire Derived Product (TDP) Grant. Present grant funding options and total cost for Council consideration.

4) Maintain the current policy. Do not pursue the use of rubber sidewalk panels adjacent to street trees at this time.

RECOMMENDATION

Staff recommends Alternative 1: Purchase and install rubber sidewalk panels to test the product at ten test sites in Fiscal Year 2007/08 using labor funded by Program 217 – Concrete Maintenance. This alternative will reduce concrete sidewalk replacement by eighteen sites which means ten sites would be rubber instead of concrete and eight other sites would not be installed

Rubber sidewalk panels should be evaluated as a pilot test project to see their value as a tool in managing the conflict of tree roots and adjacent public sidewalks. This would allow staff to evaluate the ongoing costs of maintaining rubberized sidewalks.

Reviewed by:

Marvin A. Rose, Director, Public Works
Prepared by: Leonard Dunn, Urban Landscape Supervisor

Approved by:

Amy Chan
City Manager

Attachments

A) Study Issue Paper: *Use of "Rubber Sidewalks" Adjacent to City Street Trees"*
B) Tree Root Development
C) Concrete and Tree Root Mitigation
D) Alternative Sidewalk Test Sites
E) Rubber Sidewalk Specifications
F) Rubber Sidewalk LEED Description

ATTACHMENT A

Proposed New Council Study Issue

Number	DPW 17
Status	Pending
Calendar Year	2007
New or Previous	New
Title	Use of 'Rubber Sidewalks' Adjacent to City Street Trees
Lead Department	Public Works
Element or SubElement	Transportation, Community Design

1. What are the key elements of the issue? What precipitated it?

During a presentation to Council by a Sunnyvale resident regarding the potential study issue "Street Tree Policy Review - Sustainability of Large Tree Species" it was suggested as a mitigation measure to avoid concrete sidewalk replacement by city street tree roots, that the City use "rubber sidewalks." Councilmembers Chu and Swegles requested that the use of rubber sidewalks be studied for potenial use in Sunnyvale.

The study would explore the pros and cons of using "rubber sidewalks" including fiscal impact, liability issues , environmental impacts, etc.

2. How does this relate to the General Plan or existing City Policy?

Land Use and Transportation Element

Goal C 3 Attain a Transportation System that is Effective, Safe, Pleasant, and Convenient
Policy C 3.4 Maintain Roadways and traffic control devices in good operating condition
Policy C 3.5 Support a Variety of Transportation Modes
Action Statement C3.5.2 Require Sidewalk installation in Subdivisions

Municipal Code 13.12.010. Sidewalk defined—Provisions deemed separate and alternate procedure.

As used in this chapter "sidewalk" includes a park or parking strip maintained in the area between the property line and the street line and also includes curbs, gutters, bulkheads, retaining walls or other works for the protection of any sidewalk or of any park or parking strip or any of the above. This chapter constitutes a separate and alternative procedure for performing, and collecting the cost of, the work specified herein. The procedures set forth in this chapter are in addition to and the limitations imposed by this chapter do not affect the powers conferred or procedures prescribed by Charter or general law. (Prior code § 7-3.01).

Municipal Code 18.12 DESIGN STANDARDS - Section 18.12.160 Sidewalks.

(a) All subdivisions shall have sidewalks.

(b) Where required, sidewalks shall be installed to grade on all streets and shall be constructed monolithically with the curb and gutter and parallel with the street right-of-way line, or at a location approved by the director of public works.

(c) Sidewalks, when required, shall be constructed to a minimum width of five feet in all subdivisions, and may be required at a greater width in multi-family or commercial zoning

districts. Where sidewalks are otherwise required in accordance with Section 19.46.055, the director of public works shall have the discretion of requiring less than standard sidewalk width where topographic difficulties or lack of space would reasonably prohibit the installation of a standard width sidewalk.

(d) Where sidewalks are required, the director of public works shall have the discretion of determining that a sidewalk or a portion of a sidewalk not be installed if topographic difficulties or lack of space would reasonably prohibit the installation of a sidewalk. (Ord. 2414-92 § 1 (part): Ord. 2336-90 § 1: Ord. 2194-86 § 1 (part)).

Municipal Code 19.38.080 Sidewalks--Industrial districts

(a) Except as may be permitted by use permit or design permit, all uses within the M-S (industrial and service) and M-3 (general industrial) districts shall provide sidewalks along public street frontage. Such sidewalks shall comply with all applicable specifications and other requirements of Title 13 of this code, with the exception that alternate surface materials, colors and design thereof may be authorized by use permit or design permit; provided that durability, safety and compatibility with adjoining improvements is at least equivalent to the minimum specifications contained in Title 13. Such sidewalks shall be required at the time of any of the following and may be made a condition of issuance of any building permit, certificate of occupancy or other permit required for any of the following:

(1) New construction;

(2) Reconstruction, as defined in subsection (b) of any building or buildings, involving ten percent of the gross building area, or five thousand square feet, whichever is less; or

(3) Expansion of existing individual buildings by ten percent or more of existing gross floor area, or by five thousand gross square feet, whichever is less; or

(4) Change in use requiring a tentative map, special development permit, use permit or design permit having the potential to cause a significant increase in pedestrian traffic.

3. **Origin of issue**

Council Member(s) Chu, Swegles
General Plan
City Staff
Public
Board or Commission none

4. **Multiple Year Project?** No **Planned Complete Date** 11/30/07

5. **Expected participation involved in the study issue process?**

Does Council need to approve a work plan? No
Does this issue require review by a Board/Commission? No
If so, which?
Is a Council Study Session anticipated? No
What is the public participation process?
Public will be polled for comment through public announcement through advertisement in the Quarterly Report, KSUN bulletin boards and contact through the Community Outreach Coordinator's e-mail contact system to all of the Sunnyvale Neighborhood Associations.

6. **Cost of Study**

Operating Budget Program covering costs
Program 217 - Concrete Maintenance
Project Budget covering costs
Budget modification $ amount needed for study
Explain below what the additional funding will be used for

7. **Potential fiscal impact to implement recommendations in the Study approved by Council**

Capital expenditure range	$501K or more
Operating expenditure range	$101K - $500K
New revenues/savings range	None

Explain impact briefly
Depending on the outcome of the study, the use of rubber sidewalks could increase the cost of sidewalk replacement from the current cost of $12 per square foot to approximately $36 per sq.ft.

8. **Recommendation for this calendar year**

Board or Commission ranked this study issue ____ of ____
Board or Commission ranking comments
Staff Recommendation None

If 'For Study' or 'Against Study', explain

9. **Estimated consultant hours for completion of the study issue**

Managers

Role	Manager				Hours
Lead	Dunn, Leonard	Mgr CY1:	50	Mgr CY2:	0
		Staff CY1:	30	Staff CY2:	0

Total Hours CY1: 80
Total Hours CY2: 0

Note: If staff's recommendation is 'For Study' or 'Against Study', the Director should note the relative importance of this Study to other major projects that the Department is currently working on or that are soon to begin, and the impact on existing services/priorities.

Reviewed by

Mark A. Rose — 12/6/06

Department Director **Date**

Approved by

Roger Allen for Arthur — 12-5-06

City Manager **Date**

Tree Root Development

To understand the problem of tree roots displacing concrete one must understand tree root growth and development. Tree root growth is a function of genetics of a particular tree species, soil environmental conditions and physics. In general tree root development is predicable. For trees, roots have two primary functions – water and mineral absorption and physical support. As a tree gets older and larger the support function of roots is critical. Indiscriminant removal of tree roots can lead to whole tree failure which for street trees has a high probability for serious property damage and bodily injury.

Trees develop five types of roots, tap root, lateral roots, heart roots, sinker roots, feeder roots.

- Tap Roots – The tap root develops from the germination of the seed of the tree. The tap root provides for a young tree's initial survival. Typically tap roots are lost as the tree ages and if they do remain they are short, five feet or less, and do not support the mature tree.
- Lateral Roots – These roots typically grow parallel to the soil surface and can be varying depths below the soil surface. The depth of these roots is a function of genetic predisposition and soil environmental conditions. These roots have several functions, physical support, water and mineral intake and transport. Lateral roots are primary structural support roots.
- Heart Roots – Heart roots are primarily anchorage roots. They emanate from root crown at oblique angles down into the soil. Typically these roots grow down and away from the root crown at angles up to 45° from vertical and are usually short, four to six feet long.
- Sinker Roots – are found on lateral roots on many tree species. These roots are small and grow vertically out of the bottom of the lateral roots. These roots provide anchorage for the lateral roots as well as explore deeper soil for water and minerals.
- Feeder Roots – Feeder roots are very small roots, 1mm or less in diameter and usually form reticulated masses. Feeder roots can be anywhere on any root type. The soil environment must be excellent for these roots to develop.

Tree root systems are quite variable but have a general pattern of development. Because city street trees are planted from nursery container they typically do not have a functional tap root. The primary roots that develop from container grown trees are lateral roots and heart roots. The pattern is radial around the trunk of the tree. The lateral roots are the roots that do most of the uplifting of sidewalk and curb and gutter.

Overall tree root systems are shallow; 95 % of all mature tree roots are in the top five feet of soil with most in the top two feet

Trees by their nature grow in vertical columns of varying heights and widths. Trees have one to many vertical trunks that transfer all the loads of the crown (the entire above ground portion) of the tree down the trunk(s) to the ground. Tree development is dynamic. Branch, truck and root growth is in response to loads they bear. As a tree ages it gets heavier and its canopy carries more wind loads. All these loads generate an increase in wood tissue. Tree branches get wider as they approach the trunks or main scaffold branches. Tree trunks get wider as they approach the ground. All this is in response to the loads bearing on them.

Tree roots develop where conditions are favorable and respond to the dynamic loads transferred to them. In this process lateral roots grow out from the tree and grow into areas necessary to perform their functions. The major support roots of a tree typically can be identified as the ones that increase in diameter as the approach they root crown at the base of the trunk. Major support root must be protected. Indiscriminant lateral or heart root removal will jeopardize the stability of the tree.

As tree roots grow in diameter, the force generated can be quite strong. Roots can exert a radial force ranging up to 500 pounds per square inch. Four-inch thick sidewalk concrete weighs no more than one-half pound per square inch or seventy-two pounds per square foot. Although five-foot wide sidewalk ten feet long can weigh up to 3,600 pounds, a root immediately under a concrete sidewalk can easily exert a tremendous upward force that can crack the concrete. With concrete relatively weak in tension, the force of a growing root can relatively easily fracture a four-inch thick sidewalk and with continued growth will raise the concrete.

From years of empirical observation in Sunnyvale, roots that displace concrete are either immediately under the sidewalk or above the subsoil below the sidewalk. The subterranean profile of a Sunnyvale sidewalk begins with the subgrade. The standard in Sunnyvale has the subsoil at eight inches below finish grade, compacted to a high density, then four inches of base rock is added and compacted with the final course being four inches of concrete. When lateral roots meet this vertical profile they extend into the interfaces between the layers. As these lateral roots grow in diameter they will fracture the concrete and displace it.

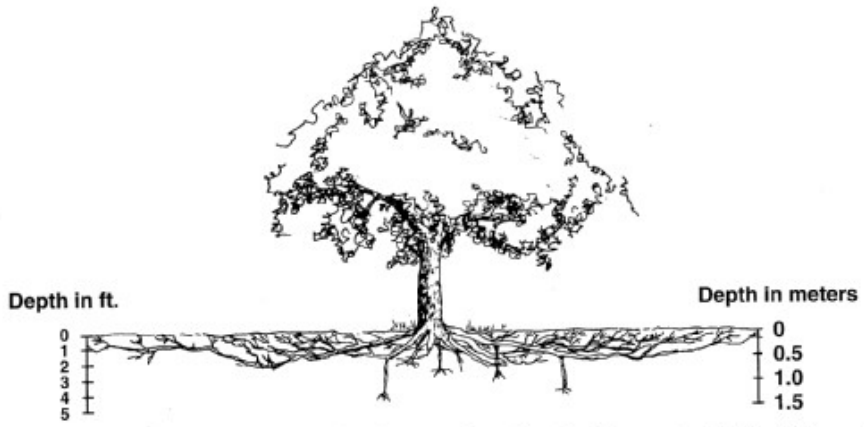


FIGURE 2-19 In mature trees, the taproot is either lost or reduced in size. The vast majority of the root systen composed of horizontally oriented lateral roots.

Whole Tree Development Profile

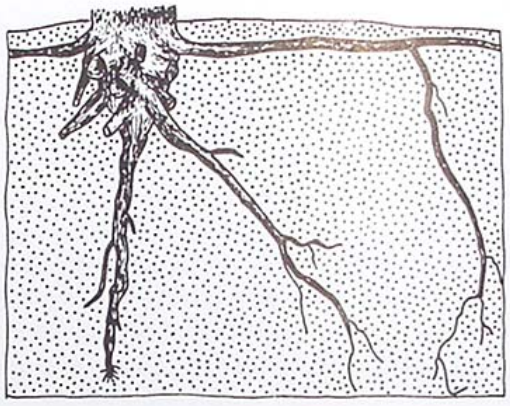
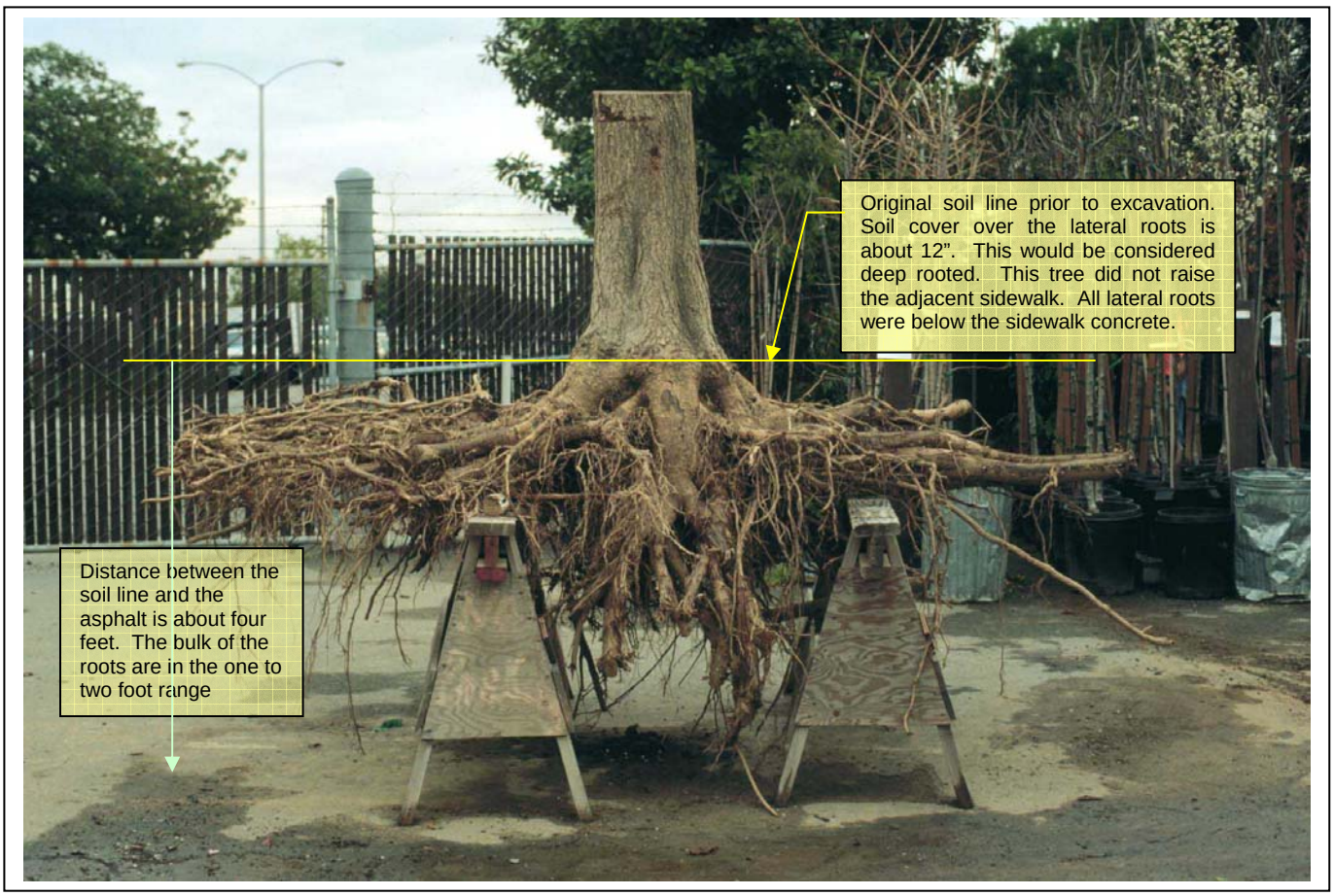


FIGURE 2-18 Types of roots that may occur on a mature tree. The vertical taproot is usually choked out by roots above. The heart root grows at an angle from the buttress of the trunk (root collar). Horizontal lateral roots are usually near the surface. Sinker (striker) roots grow downward from lateral roots. *(Adapted from Fayle, 1968.)*

Primary Root Types on Mature Trees

Illustrations taken from *'Arboriculture – Integrated Management of Landscape Trees, Shrubs, and Vines'* 4th ed., R.W. Harris, J.R. Clark, N. P. Matheny, 2004



Ginkgo Tree – Root Plate

This Ginkgo tree was a female tree that was excavated in the early 1990's on Kelsey Drive. It was hydraulically excavated to capture the root system as it radiated away from the root crown collar. This tree was 12" in diameter at 54" above the soil line.

The roots parallel to the soil line are **lateral roots**. The roots near trunk going down are **heart roots**. Small **sinker roots** can be seen growing out of some of the lateral roots. The lateral roots and heart roots together are the roots that are actually supporting this tree.

Lateral Roots under Sidewalk of a Liriodendron Street Tree

This example of a Tulip Tree – *Liriodendron tulipifera* street tree had many lateral roots growing under the sidewalk. These roots are all in the same plane because they grew in the interface between the underside of the concrete sidewalk and the base rock the concrete was originally poured. Although this is an extreme example, any one of the lateral roots shown above could have lifted and displaced the sidewalk.

Concrete and Tree Root Mitigation

Currently, in Sunnyvale, there are several methods and procedures used to mitigate concrete tree root conflicts. The first comes with planting of a new tree. Keeping the lateral roots emanating out from the new tree from growing into the interfaces presented in the vertical profile, a barrier is placed between the tree and the sidewalk. This barrier is close to the concrete but not placed against it. The barrier is a high-density poly-ethylene plastic sheet 40 mills (thousandths of an inch) thick and twelve inches wide. The barrier is set four inches back from the sidewalk and extends down twelve inches vertically into the soil. The barrier runs parallel to the side ten feet either side of the tree for a total distance of twenty feet. The vertical root barrier inhibits lateral roots from easily growing into the subterranean sidewalk profile interfaces.

The barrier is placed close to the sidewalk. University of California and University of Florida research on root growth and development have demonstrated that roots do not stay at down once they have past under a subterranean vertical soil barrier. If the soil conditions are favorable lateral roots do grow back to the subterranean position they are genetically predisposed. The university research showed that roots could return to levels of control tree roots within as little as five feet. It is therefore important to keep the root barrier as near to the concrete being protected not the tree.

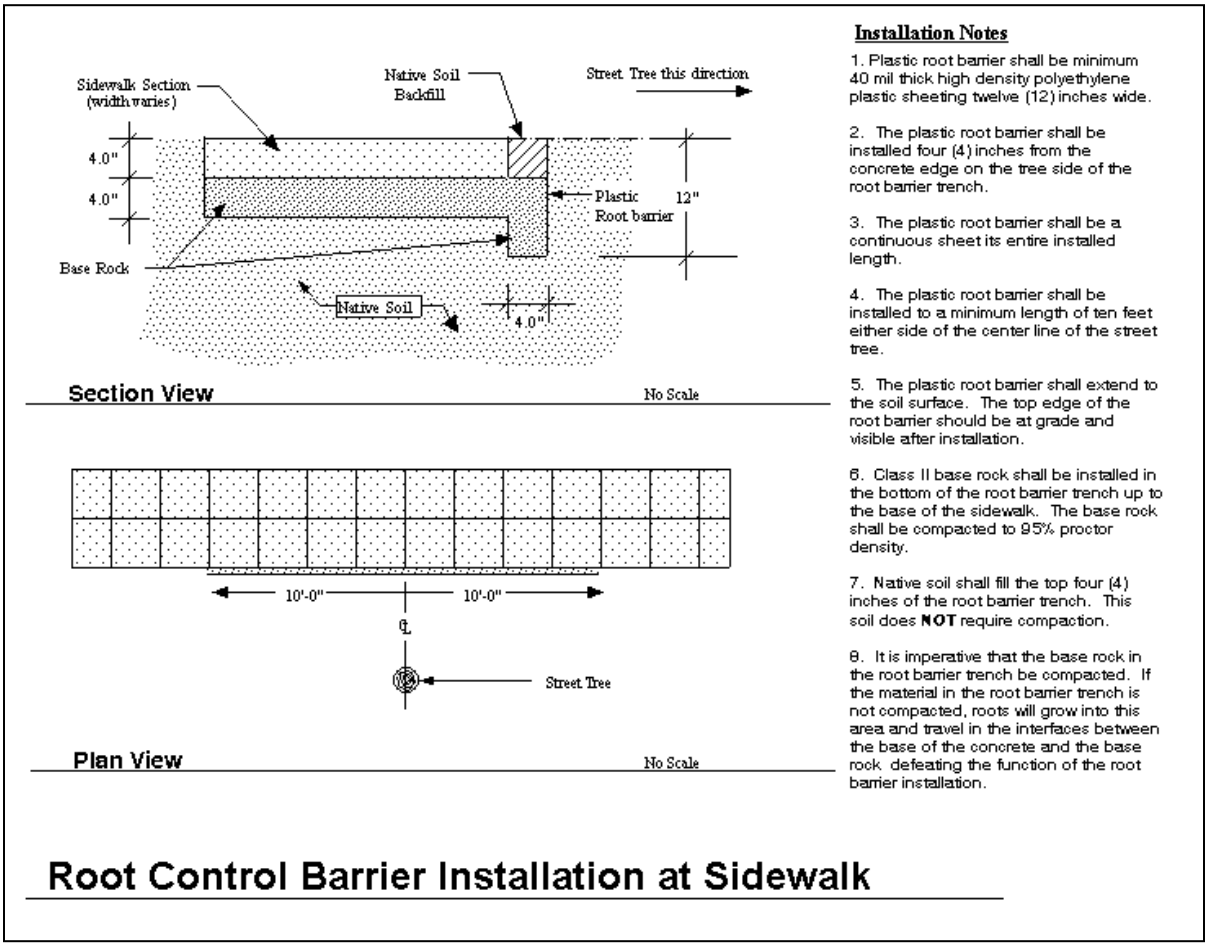
Routine root barrier installation for newly planted trees did not begin in Sunnyvale until 1997. With over 37,000 street trees most of them were planted without any root barrier adjacent to the sidewalk. Therefore, there are many sites in Sunnyvale with large mature street trees that are lifting concrete sidewalks. Several methods are used to mitigate these concrete tree root conflicts. Where concrete is displaced due to tree roots, the concrete is either ground with a concrete milling machine if the displacement is one inch or less or displacements greater than one inch have an asphalt ramp patch installed to make the site safe for pedestrians. Ramp patched sidewalk displacement sites are scheduled for future replacement.

At the time of replacement and the displaced sidewalk is removed, the tree roots are examined by the City Arborist. The Arborist decides which roots can be safely cut and removed and which must remain. The root evaluation requires an ISA certified arborist with special training in tree roots. Where the arborist has determined which roots can be cut and which must remain root pruning and root protection is performed. Roots that can be cut are severed cleanly at a root branch intersection similar to how above ground tree branches are pruned. Some tree species can

tolerate a shallow root pruning with a root-pruning machine where roots are severed to a depth of nine inches from the sidewalk surface.

Where roots cannot be removed because it would jeopardize either the health and/or stability of the tree, steel plates are installed. The steel restrains the roots radial expansion and can remain under the new sidewalk installed above it.

Sidewalks as well as curbs are adjusted in some locations to accommodate the root crown flare. These transitions allow for the root crown flair without pushing against the sidewalk or curb and gutter.



Steel Plates Installed Above and Below Root

Ten gauge steel plates are installed above and below a lateral root that must remain. The steel will confine the radial root growth of this root, here under a curb and gutter. After base rock is installed around these steel plates the new curb and gutter is installed. The steel plates below will not allow this root to raise the new curb and gutter.

Curb and Sidewalks Transitions to Accommodate Root Crown Flare

To accommodate this large Ash tree the curb and sidewalk was modified. This process helps avoid root damage that will jeopardize the health and stability of this large street tree.

Current Sunnyvale Sidewalk Test Sites

Interlocking pavers are commonly used as an alternative to poured in place concrete for sidewalks, patios, driveways, etc. In Sunnyvale interlocking pavers have been used in several locations. Our first experimental site is at Sunnyvale's commercial property at 1024 Morse Avenue. This site's treatment uses a wire mesh below the pavers over the top of an existing Casuarina tree roots. The root has been left in place to observe how the radial expansion of the root affects the lifting of the pavers. Ideally as the root increases in diameter and comes in contact with the wire mesh and pavers, the pavers will be lifted in unison. Without the wire mesh, individual pavers could be lifted independently and create a tripping hazard. To date the pavers have not been raised by the tree root left remaining under the pavers.

Our second site using interlocking pavers is near city hall on Charles and Olive Avenues. At this site interlocking pavers are used adjacent to existing Liquidambar street trees. Here selective root pruning, installation of steel plates and installation of vertical root barrier were used but instead of installing concrete as the sidewalk surface interlocking pavers were used.

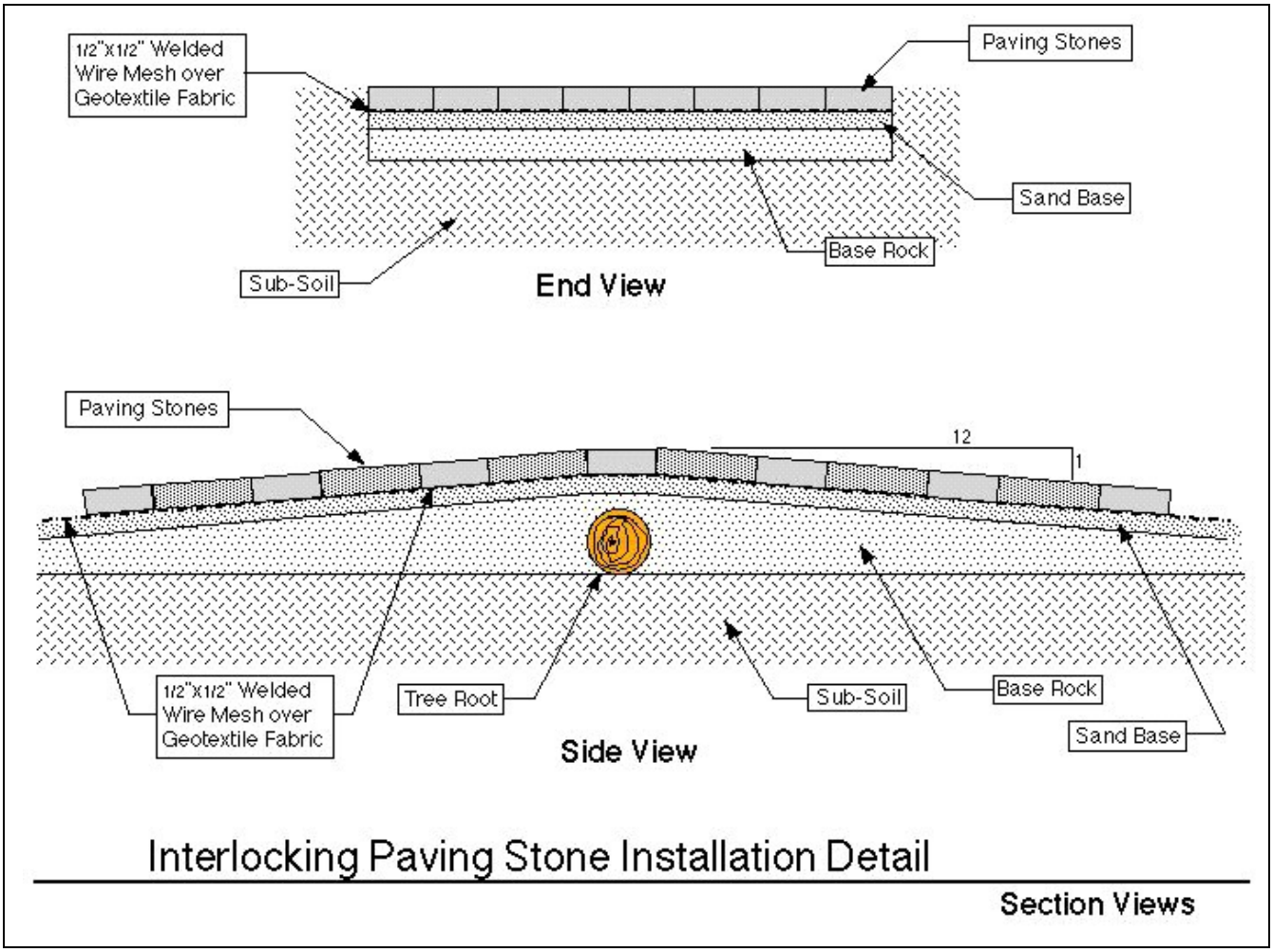
Where a tree is completely surrounded by concrete, the tree's roots can severely damage the concrete. To mitigate this problem, researchers at Cornell University developed structural soil. Cornell University Structural Soil® is a granitic rock mixture ranging from three-quarter inch to one and one half inches. To this rock is added a clay loam soil. The clay loam soil component adds a water and mineral nutrient reservoir to the stone. The structural soil is used a base material under the sidewalk. The large voids in the structural soil provide spaces for tree roots to penetrate without lifting the concrete sidewalk above. The use of structural soil is the standard in the new Sunnyvale downtown for streets with large sidewalks and no street side open space. The first use of CU Structural Soil® was at the Mozart buildings and at Plaza del Sol under the sidewalk around the city street trees in curbside tree wells.

Structural soil and interlocking pavers have been used in combination at several sites. The first site is at 360 W. Olive just east of Mathilda. Here structural soil is used with interlocking pavers in a planting of Podocarpus street trees. On Fair Oak Ave adjacent to Victory Village, structural soil and interlocking pavers are used in a planting of native Valley Oak trees. Most recently interlocking pavers and structural soil have been used on Murphy Ave near Iowa and on Olive Ave west of Mathilda. The Olive Ave at Mathilda site is doubly experimental. Due to a traffic accident, the existing Liquidambar street tree was knocked down. Here the replacement tree is the fruitless variety of Liquidambar, *Liquidambar sytraciflua* 'Rotundiloba'. This variety is the only known variety of Liquidambar not to produce the typical hard cone fruitballs. The last street tree on Olive Avenue at Mathilda has structural soil to mitigate

root conflicts as well as debut the **Rotundiloba** variety of fruitless Liquidambar tree.

1024 Morse Ave Interlocking Paver Test Site

This site is at Sunnyvale's commercial property at 1024 Morse Avenue. The tree on the right is a Casuarina tree. Several years ago a lateral root displaced the concrete sidewalk here. The tenants needed to have the tripping hazard on the adjacent sidewalk mitigated. This site has interlocking concrete pavers overlaying a weld wire mesh that are over the original Casuarina tree root. This site is testing if the pavers will lift in unison as the tree root below continues to grow and expand.



This illustration is the design detail for the Interlocking paver test site at 1024 Morse Avenue. This design uses a weld wire mesh to see how the pavers respond when a root comes in contact with the underside of the pavers. The desired result is for the pavers to rise in unison rather than have an individual paver pop-up causing a tripping hazard.

RUBBERSIDEWALKS, INC.

PROBLEM

Concrete sidewalks are uplifted by tree roots.

Trees struggling for air and water develop large and invasive root systems under concrete.

SOLUTION

A MODULAR SIDEWALK SYSTEM

Easy and economical to install, tree roots grow less invasively beneath Rubbersidewalks offering a new strategy for sidewalk maintenance. Proven and tested in cold weather climates.

Rubbersidewalks are made of 100% recycled California tire rubber. Each square foot diverts one passenger tire from land fills.

Three Years Later

Rubbersidewalks modularity allow roots to be periodically inspected and trimmed as needed.

Rubbersidewalks, Inc. wishes to thank the California Integrated Waste Management Board for their continued support.

SPECIFICATIONS

RUBBERSIDEWALKS - MUNICIPAL

Modular recycled-California-tire-rubber interlocking sidewalk paving system.

PRODUCT DESCRIPTION

Rubbersidewalks are made from 100% recycled crumb rubber from waste tires, mixed with polyurethane resin and colorant, and molded under pressure using steam-generated heat to reduce energy demands. This produces a strong and durable part that meets all requirements of sidewalk-worthiness, including stable grade, non-vibration in compliance with ADA requirements, and high coefficient of friction for non-skid both dry and wet. Rubbersidewalks are hard enough for skateboarders, rollerblades and spikes, yet resilient enough to provide safe passage for all pedestrian and wheeled traffic. Pavers are available in various sizes and colors, and are reversible. Expected life is minimum 16 years.

RUBBERSIDEWALKS' SERVICES

Services Include: • Site registration and tracking in Rubbersidewalks' database • Maintenance schedule & notification of maintenance due • Photo documentation of site, before and after • Site Banner • Educational materials for local school district

Available upon request • Certified installation services (in some regions) • Consulting arborist services • Long term Maintenance Service • Press Kit materials • Installation Manual and DVD

RUBBERSIDEWALKS' PRICING

Rubbersidewalks pavers cost $7.00 per square foot plus accessories, shipping and tax if applicable.

Material:	100% recycled California crumb rubber, urethane resin binder & colorant.
Size:	2' x 2.5' x 1.875" 5 sq ft (for 4 or 5 foot wide sidewalks), 2' x 2' x 1.875" 4 sq ft.
Weight:	10.8 lbs per square foot (54 lbs; 44 lbs).
Surface:	Crumb rubber molded texture, all edges 1/8" radius (both sides identical)
Colors:	Gray, terra cotta, black, black with white chip (additional colors available upon request). Paver expected to darken slightly in the first two months then remain stable. UV lab tests show no change after two years. Surface appearance may vary due to inconsistence in granulated waste tire rubber.
Maintenance:	Sweep, hose down or mop.
Weight Load:	3,000 pounds per square inch.
Shock Attenuation:	Under 200 g at 5'. Fall significantly less likely to cause injury or broken bones than on concrete.
Coefficient of friction:	ASTM C 1028: 0.90 dry; 0.65 wet (OSHA guidelines require that all walking surfaces satisfy a 0.5 Static Coefficient of Friction rating. In new construction and alterations, ADA specifies that a 0.6 Coefficient of Friction is recommended on all path of travel surfaces).
Taber-Abrasion:	ASTM C 501: 270 (indicates high resistance to wear).
Salt/Chloride:	ASTM B117: No change in surface; no stain or residue.
Magnesium Chloride Soak:	No change in surface; no stain or residue.
Xenon Arc Weathering:	No change after exposure to sunlight two-year equivalent.
Flame Spread ASTM E162:	Index 131.18 at average temperature of 157.7 C (Surface flammability ANSI Z124.1 and Z124.1 allows Index of 450 or less). If exposed to open, constant fire, pavers are likely to smolder. Lit cigarettes, cigars or matches can burn on paver until they self-extinguish.
Porosity:	Permeable at module seams; immediate drainage of water into ground; minimal run off into storm drain.
Freeze-Thaw:	ASTM C 1026: Product exposed to 15 cycles of freeze-thaw at 0 Degrees for 90 days. No change. No facial defects. No signs of crazing, chipping, spailing or cracking. Product frozen at 0 degrees was subjected to impact with no change.
ADA Compliance:	Low vibration; concrete-to-Rubbersidewalks transition imperceptible; high coefficient of friction both dry and wet; surface hardness supports all pedestrian and wheeled traffic.
Modularity:	Rubbersidewalks is a modular sidewalk system. Pavers are interconnected and can be periodically opened for tree root or seismic maintenance.
LEED Credit:	Rubbersidewalks qualifies for a minimum 4 LEED credits for Recycled Content, Heat Island Affect Non-Roof and Regional Materials.
Other:	• 100% California recycled tire rubber, with polyurethane binder. Non-toxic. All components inert solids. No volatile organic compounds. Product does not leach, off-gas, or produce rubber dust particles. • Rubbersidewalks reduces sound of all pedestrian or wheeled traffic.

SOLE SOURCE

Rubbersidewalks is a sole source product, developed exclusively by Rubbersidewalks, Inc. for the public right of way and other landscaping applications, marketed and manufactured by Rubbersidewalks, Inc. Rubbersidewalks modular sidewalk system has been tested and proven effective for use in public right of way applications (sidewalks, walkways, tree wells), and proven beneficial to the health and maintenance of urban trees. Accept no substitutes. There is only one Rubbersidewalks. Products called Rubber Sidewalk, Rubber Sidewalks, or Rubbersidewalk are NOT REAL Rubbersidewalks.

Rubbersidewalks, Inc. is a small, woman-owned California business.

AVAILABLE COLORS:

GRAY

TERRA COTTA

BLACK

RUBBERSIDEWALKS, INC.

The resources of the earth are limited. Recycling is limited only by our imagination and effort...

Ph 310 515 5814 • Fax 310 515 5314 • 2622 West 157th Street, Gardena, CA 90249

E-mail: info@rubbersidewalks.com • Web: www.Rubbersidewalks.com

RUBBERSIDEWALKS, Inc.

Modular Recycled-Tire-Rubber Sidewalk Paving System

Good for the Environment

Cities, architects and builders throughout the country want to make environmentally responsible choices as they struggle to provide safe sidewalks, preserve their urban trees, and control their budgets.

Rubbersidewalks is the Solution:

- ✔ Reducing sidewalk damage repair and replacement costs
- ✔ Diverting waste tires from landfills
- ✔ Preserving trees that contribute to clean air and public health
- ✔ The proven environmental alternative to concrete sidewalks

Cost Savings!

Good for the Budget

- ✔ Eliminate costly injury claims for trip & fall accidents
- ✔ No broken sidewalks due to tree roots or freezing
- ✔ Concrete must be ground down or completely demolished and replaced
- ✔ Easy remove-and-replace for periodic tree root inspection or underground utility access

READER'S DIGEST AMERICA'S 100 BEST 2007

Good for the Public

- ✔ Safe for all pedestrian and wheeled traffic
- ✔ Safe, non-toxic and flame resistant
- ✔ Absorbs the sound of foot and wheeled traffic
- ✔ Can be used in tree wells and sidewalks
- ✔ Resilient, firm, comfortable & healthier walking/jogging
- ✔ Colors and textures resemble concrete, granite or adobe
- ✔ One-square-foot diverts one passenger tire waste from landfill

Rubbersidewalks, Inc. 2622 West 157th Street, Gardena, California 90249 Tel - 310.515.5814
Sales Office: Tel - 714.375.3017 Fax - 714.375.1741 Website - Rubbersidewalks.com

RUBBERSIDEWALKS, Inc.

LEED Defined and New Recycled Products

What is LEED, and What Does Rubbersidewalks Have to Do With It?

LEED is the Leadership in Energy and Environmental Design Green Building Rating System, which was developed by the U.S. Green Building Council (USGBC), providing standards for environmentally-sustainable construction.

LEED was Created to:

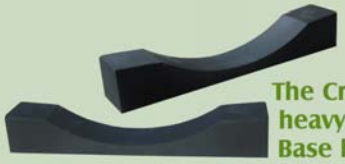
- ✔ Define "green building" by establishing a common standard of environmental impact measurement
- ✔ Stimulate green competition, by promoting integrated, whole-building design practices
- ✔ Recognize environmental leadership in the building industry
- ✔ Raise consumer awareness of green building benefits

The rating system addresses five major areas: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials & Resources, and Indoor Environmental Quality. The system offers four levels of accomplishment: LEED Certified, Silver, Gold, or Platinum, according to how well the building meets criteria in the rating system.

Rubbersidewalks' products earn rating points toward LEED certification.

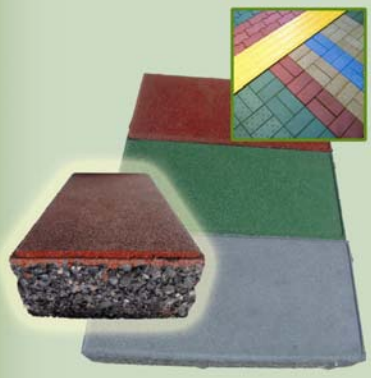
New Recycled Content Products

We're constantly developing new products, and partnering with companies whose products represent the best innovations in sustainability, recyclability and public safety. Ask us if you have any questions about any of our products, recycled tire content, or other information.



The Cradle, heavy duty Base holds pipe & rebar off the ground & prevents rolling

Rubberoo Recycled Rubber Mulch w/MicroBan



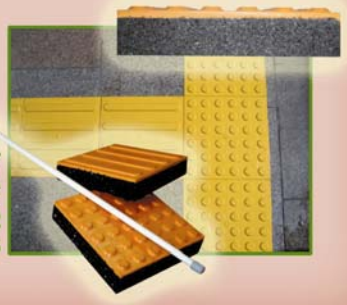
Recycled Rubber Paver Bricks

RubberForm Durable Sign Bases & Speed Bumps

Eco-Blok, Barrier-Blok, & Filter-Blok drainage and water flow control systems

EnvironFoam, Prefab Structures 100% recycled materials, easily erected and transported

Ad-A-W8, the first and only weight to secure bases and A-frames



Modular Detectible Warning Systems